Efficiency loss in PbPb due to EMD

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Ultra-Peripheral Collisions meeting

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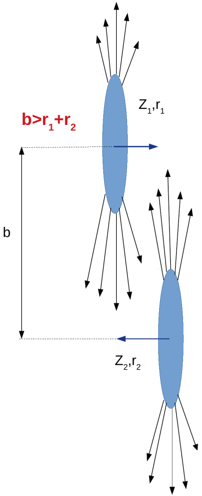
Photoproduction of J/ψ

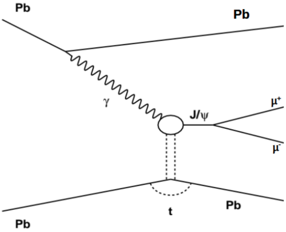


- Photon flux $\propto Z^2$

$\Rightarrow$ Photon-induced $Pb - Pb$ interactions

- Due to Vector Meson Dominance - vector meson is produced very likely

$\Rightarrow$ Photoproduction of J/ψ vector meson

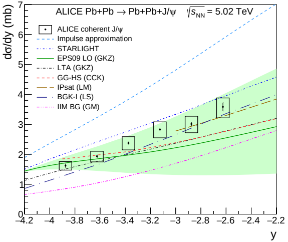


- Measuring cross section of J/ψ photoproduction in UPC

Why is this process interesting to study?

$$\frac{d\sigma_{\gamma Pb \rightarrow J/\psi Pb}}{dt}\Big|_{t=0} = \frac{M^3_{J/\psi}\Gamma_{ee}\pi^3\alpha_s^2(Q^2)}{48\alpha_{em}Q^8}[xg_{Pb}(x, Q^2)]^2$$

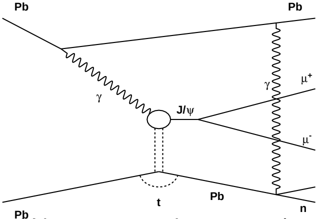
$\rightarrow$ Tool to study gluon densities at small$-x$ values



Shreyasi Acharya et al. arXiv:190406272, can be found here.

Additional process: EMD

Independent additional photon-induced interaction of the same pair of nuclei can occur. One or more neutrons (not only!) are produced.



- We separate data sample into four neutron classes - (0n0n),(0nXn),(Xn0n) and (XnXn)
- Measuring cross section in different neutron classes

Why separation into neutron classes?

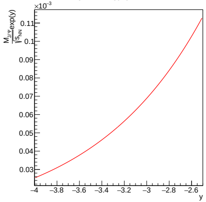
$$\frac{d\sigma_{PbPb\rightarrow \mathrm{J}/\psi PbPb}(y)}{dy} = N_{\gamma Pb}(y)\sigma_{\gamma Pb\rightarrow \mathrm{J}/\psi Pb}(y) + N_{\gamma Pb}(-y)\sigma_{\gamma Pb\rightarrow \mathrm{J}/\psi Pb}(-y)$$

- We believe it helps us to disentangle these
- $x = \frac{M_{\mathrm{J}/\psi}}{\sqrt{s_{NN}}} exp(\pm y)$

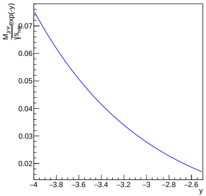
$\Rightarrow$ And reach even lower values of $x \sim 10^{-5}$!

- **All good. Where is the problem then?**

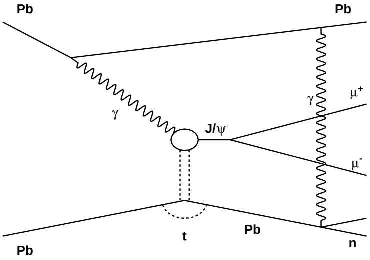
High energy photon



Low energy photon

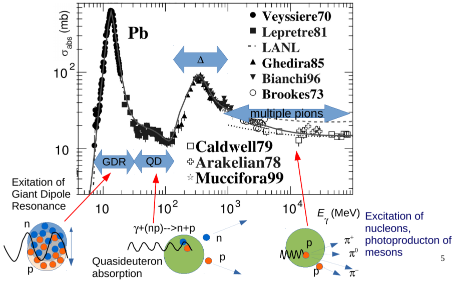


Electromagnetic dissociation



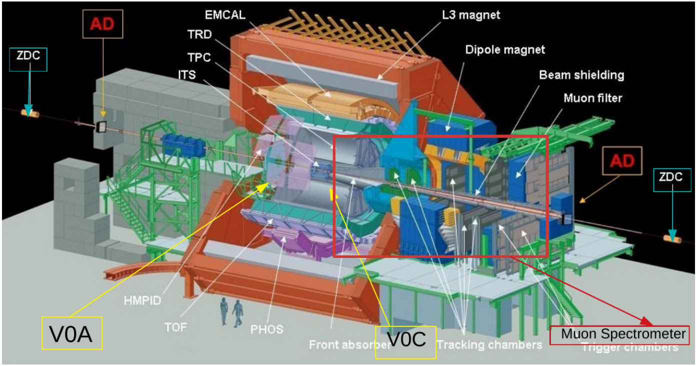
- In an EMD event - at least one neutron is emitted ($\sim 97\%$).
- Less frequent production of charged particles has not been taken into account.

Taken from I. Pshenichnov talk, can be found here.



We are losing these events!

ALICE subdetectors



Problem

- Main trigger used in the published analysis:

⋆ CMUP11-B-NOPF-MUFAST = !0VBA & !0UBA & !0UBC & 0MUL

- Veto on V0A, ADA and ADC - detection of charged particles produced
- Additional offline veto applied

- No control trigger allowing the correction!

Solution

- Another trigger active in 2018 data taking:

⋆ CMUP6-B-NOPF-MUFAST = !0VBA & 0MUL

- Separation of the sample into neutron classes (0n0n), (0nXn), (Xn0n) and (XnXn)
  - Defined via activity in ZDC detectors

- No need of correction for classes (0n0n) and (0nXn)
- Classes (Xn0n) and (XnXn) need to be corrected:
  - Correction for events caused by pile-up in V0A
  - Correction for events lost due to online V0A veto

  ⋆ CTRUE, C1ZED samples to compute correction factors

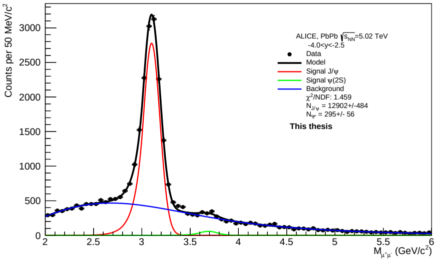
$\Rightarrow$ **Data sample including EMD processes.**

Selection of J/ψ candidates

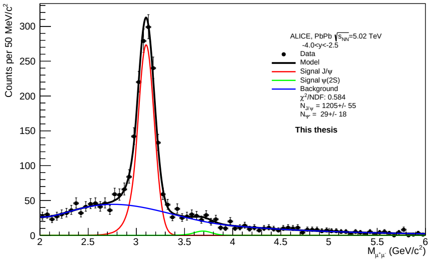
- Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.02$ TeV during LHC Run 2
- Event selection
  - Two unlike-sign muons in muon spectrometer
- Muon selection
  - The opposite electric charge
  - The dimuon rapidity: $-4 < y_{\mu\mu} < -2.5$
  - The transverse momentum: $p_{\mathrm{T}} < 250$ Mev/c
  - The invariant mass: $2.85 < M_{\mu\mu} < 3.35$ GeV/c^2
- Separation into neutron classes using information from ZDC detector

Invariant mass distributions

- Invariant masses are fitted for all neutron classes and the number of J/ψ candidates is extracted.

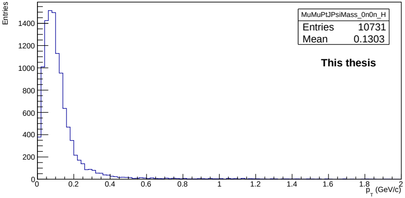


Neutron class (0n0n)

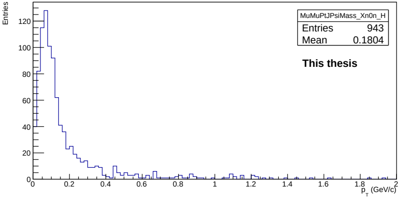


Neutron class (Xn0n)

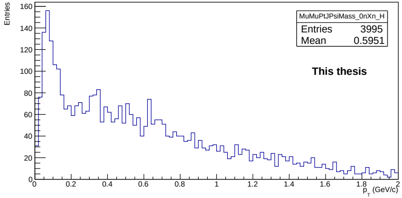
Transverse momentum distributions



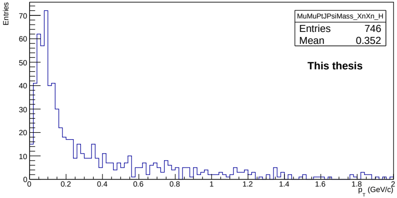
(0n0n)



(Xn0n)



(0nXn)



(XnXn)

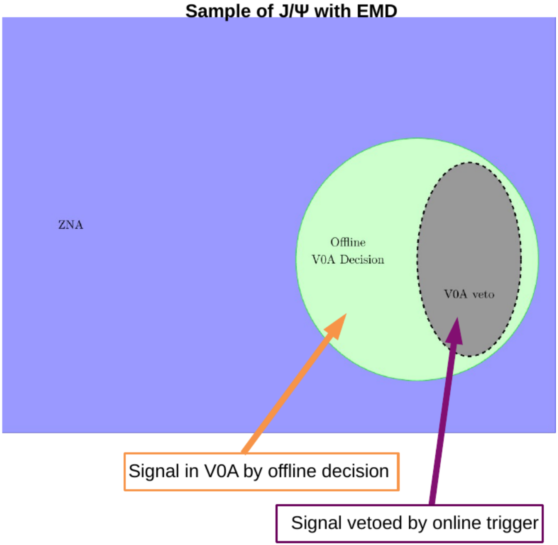
- Very different background in different neutron classes!

Incoherent contribution

- Sample is contaminated by incoherent events.
- Tomáš Herman has produced fractions of incoherent events:
  - ⋆ $f_{\mathrm{I}} = \frac{\mathrm{J}/\psi\mathrm{incoh}+\mathrm{feed\ down J}/\psi\mathrm{incoh}+\mathrm{dissociative J}/\psi\mathrm{incoh}}{\mathrm{J}/\psi\mathrm{coh}+\mathrm{feed\ down J}/\psi\mathrm{coh}}$
  - $\Rightarrow$ $N_{\mathrm{J}/\psi\mathrm{coherent}} = N_{\mathrm{J}/\psi} \cdot \frac{1}{(1+f_{\mathrm{I}})}$
- The samples of four neutron classes have been cleaned up from incoherent contribution.

Coherent J/ψ sample

- Another collision in the same bunch crossing: pile-up
- Lost events due to the online V0A veto



1. Pile-up in V0A

- Interaction of another nucleus pair caused a signal in V0A - a pile-up event
- Determination of pile-up with CTRUE event sample

⋆ CTRUE = unbiased trigger fired in bunch crossing time window

- Finding the probability of having signal in V0A in otherwise empty detector

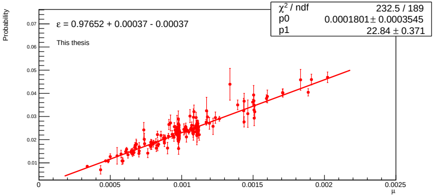


Figure: V0A pile-up in (Xn0n) class.

- ∼ 2.4% of events are caused by pile-up.

2. V0A veto correction

- Data sample triggered by 1ZED is used.

⋆ C1ZED = activity in at least one side of ZN in bunch crossing

- To get the correction factor we seek for events that are selected by the offline decision of V0A and not by online trigger:
- Veto correction factor ϵ is obtained: Correction itself: $\frac{1}{\epsilon}$
- Veto correction is needed for (Xn0n) and (XnXn) classes

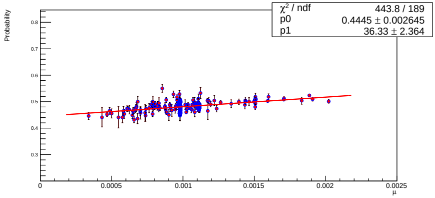


Figure: V0A veto correction factor in (Xn0n) class.

- Inefficiency of the V0A online trigger is about $\sim 44\%$

Results

- Correction factor for each neutron class and for all events is calculated:

⋆ $F_{class} = \frac{N_{\mathrm{J}/\psi\mathrm{coherent\ corrected}}}{N_{\mathrm{J}/\psi\mathrm{coherent}}}$

  - $N_{\mathrm{J}/\psi\mathrm{coherent}}$ - number of coherent J/ψ candidates in each neutron class.
  - $N_{\mathrm{J}/\psi\mathrm{coherent\ corrected}}$ = number of J/ψ candidates after pile-up correction and V0A veto inefficiency correction.

(Xn0n)

$$\boxed{F_{\mathbf{(Xn0n)}} = \frac{\mathbf{1250.77}}{\mathbf{1172.301}} = \mathbf{1.067}}$$

(XnXn)

$$\boxed{F_{\mathbf{(XnXn)}} = \frac{\mathbf{1031.85}}{\mathbf{889.299}} = \mathbf{1.160}}$$

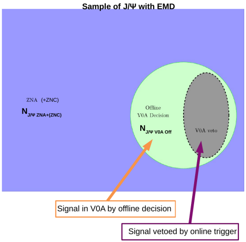
$$\boxed{F_{\mathbf{all}} = \frac{\mathbf{(12808.8+920.905+1250.77+1031.85)}}{\mathbf{(12808.8+920.905+1172.301+889.299)}} = \mathbf{1.014}}$$

Summary and outlook

- New problem was identified.
- No tools available to solve it, we got creative to find a solution.
- Corrections are very large for two of the four neutron classes.
- Selection and background subtraction has to be fine-tuned to agree with one to be used in the paper.

Thank you for your attention!

Backup



⋆ $F_{(Xn0n)} = \frac{N_{\mathrm{J}/\psi \mathrm{coherent\ corrected}}}{N_{\mathrm{J}/\psi \mathrm{coherent}}}$

(Xn0n) neutron class

⋆ ϵ_{PU} - Pile-up correction factor for each neutron class.

⋆ $\frac{1}{\epsilon_{\mathrm{veto}}}$ - V0A inefficiency correction factor for each neutron class.

- $N_{\mathrm{J}/\psi \mathrm{PU\ corrected}} = N_{\mathrm{J}/\psi \mathrm{PU\ corrected\ ZNA}} + N_{\mathrm{J}/\psi \mathrm{PU\ corrected\ V0AOff}} = N_{\mathrm{J}/\psi \mathrm{ZNA}} \cdot \epsilon_{\mathrm{PU}} + N_{\mathrm{J}/\psi \mathrm{V0AOff}} \cdot \epsilon_{\mathrm{PU}}$
- $N_{\mathrm{J}/\psi \mathrm{V0A\ veto\ corrected}} = (N_{\mathrm{J}/\psi \mathrm{PU\ corrected\ V0AOff}}) \cdot \frac{1}{\epsilon_{\mathrm{veto}}}$
- $N_{\mathrm{J}/\psi \mathrm{coherent\ corrected}} = N_{\mathrm{J}/\psi \mathrm{PU\ corrected\ ZNA}} + N_{\mathrm{J}/\psi \mathrm{V0A\ veto\ corrected}}$